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EUTROPHICATION PROBLEMS IN RESEVOIRS

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Eutrophication Problems in Reservoirs

About a year ago the Chicago Tribune issued a colorful booklet titled "Save Our Lake". It is a compilation of newspaper articles and supporting photography that tells the story of eutrophication in Lake Michigan, Lake Erie, and others of the Great Lakes. This commendable effort did much to bring to the citizenry of the region an awareness of the eutrophication problem and what it means. While held by some to be the total spread of elements in the aging process in lakes, and by other to be only the exhibited increasing productivity, the symptoms of the eutrophication process are fairly well recognized.

They include increasing availability of plant nutrients, such as nitrogen and phosphorus, loss of dissolved oxygen resources in the deep water layers, shifts in fish populations from desirable cold-water salmonids to less desirable warm-water species, and, at later stages, gradual shift from clean shoreline to floating bog, and eventually to dry land.

For many of the 100,000 small lakes of the United States, the aging process began some 12,000 years ago at the time of the continental glaciation. This is what created many of these lakes in the first place. From the time they came into being, they immediately fell victim to the aging process and, while the rates varied from lake to lake, under natural conditons the speed of change was fairly slow.

Then came people, and eutrophication in lakes moved at an accelerated rate. Rivers initially seemed untroubled by the influences of eutrophication, but there, too, evidence of increased fertility appeared. Much later, there emerged a national campaign to convert many rivers to series of pools or flow-through lakes. These circumstances are the historic setting against which eutrophication must be viewed.

The theme of this seminar series is "Reservoirs: Problems and Conflicts". No one can deny that reservoirs have many values and serve

mankind in many different beneficial ways. But is must be noted that along with these virtues, many problems and conflicts also arise. One can point, for example, to organizations that advocate the preservation of wild rivers in their natural state.

One can point to intense opposition to proposals to inundate land sites that may be of value because of their scenic qualities or archeologic significance. With respect to salmon migration in the Columbia River, questions have been raised as to the impact of dams and, recently, how best to husband resulting cool water resources to regulate temperature at desireable levels.

In relation to this theme there is also the question of reservoir impacts on water quality. Interest in this question comes from several points of view. Section 3(b) of the Federal Water Pollution Control Act (Public Law 84-660) requires that consideration be given to inclusion of storage for regulation of streamflow for the purpose of water quality control in connection with planning of any reservoir by any Federal agency. But, in addition, there is profound interest in the biological involvements in reservoirs, especially when they lead to increased expression of fertility--the same eutrophication problems that exist in lakes.

It is not surprising, then, that people in some geographic settings are concerned about excessive production of algal blooms that impair the usefulness of reservoirs or unfavorably influence the quality of water discharged downstream. There also is concern about concurrent taste and odor problems associated with excessive productivity. Sometimes there are problems with fishkills which appear to have a relationship to or result from increased reservoir fertility and production.

If in small lakes the ravages of eutrophication are permitted to run their course, the ultimate result is an extinguished lake and a final shift from water to dry land.

In reservoirs, where the product of increased production are flushed out downstream, developmental movement toward dry land moves at a much slower pace. Sometimes because of the internal workings in the deep waters of the reservoir, increased concentrations of plant nutrients are permitted to pass downstream. In some cases, as currently in Hell's Canyon, increased nutrient availability leads to an abundance of attached algal growths, such as Cladophora, which create undesirable water quality problems.

At present, there is little understanding of the mechanisms within reservoirs that determine their expressions of fertility or how to predict

during the planning stages what the production levels are likely to be. These implied questions identify areas of ignorance that call attention to needed intensified research efforts.

EUTROPHICATION PROBLEMS

In examining the impact of eutrophication tendencies in reservoirs, a number of basic points seem obvious. First, impounding fertile water in a reservoir generally leads to algal blooms or other aquatic plant problems. Conversely, in the Columbia River, with its water of low fertility, one can expect low production in impoundments. Available data show this to be true.

Studies on the Missouri River some 15 years ago when Fort Randall Reservoir was created showed that fertile, free-flowing river water is capable of noteworthy production of aquatic plants once the water becomes quiescent and clarified through sedimentation. Impoundments on the Snake River also exemplify high algal production in the presence of impounded fertile water. Similar examples occur in the TVA system, also.

Second, in the context of eutrophication, reservoirs and flow-through lakes are not fundamentally different. It is possible, therefore, to look at lakes--for which there is a much greater store of observational experience-- to obtain an understanding of principles that can be applied interpretatively to reservoirs. So far as eutrophication of lakes is concerned, there is a voluminou scientific record, and many examples can be identified on a worldwide basis.

At the moment, intensified publicity is focused on Lake Erie where it is estimated that a eutrophication prevention and remedial program will cost $1.1 billion for appropriate municipal waste treatment and $285 million for required industrial waste treatment.[1] Attention has been directed recently to Lake Michigan, also, in an intensified effort to prevent this vital water resource from progressing to the stages of deterioration through which Lake Erie has passed. One can also cite Upper Klamath Lake in southern Oregon as an example of a lake which has moved far down the eutrophication pathway almost solely under natural influences.

Many other examples of eutrophication problems could be cited both in the United States and worldwide.

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1. Lake Erie Report--A Plan for Water Pollution Control. U.S. Dept. of the Interior, Federal Water Pollution Control Administration, Great Lakes Region. 107 p. Aug. 1968.

Third, there are two symptoms of eutrophication that people find most distasteful: (1) algal blooms, because they make the water green and unattractive, produce foul odors upon decay, and generally prohibit many water uses, and (2) over-abundance of unwanted rooted waterweeds that interfere with swimming, fishing, boating, and other uses. Occasionally there are other special problems that could become common in reservoirs.

In Lake Winnebago in Wisconsin, for example, the outflow of algae from the lake into the Lower Fox River has created serious water quality problems. During some summer periods in the past as much as 660,000 lbs. of BOD in the form of algae have been discharged downstream. The oxygen demand of an algal mass of this magnitude is equal to the raw sewage from almost 4,000,000 people. Similar problems have arisen in the Klamath River in Oregon as a result of the outflow of algae from Upper Klamath Lake. Under conditions such as these, the algae obviously compete with all other waste sources for the limited assimilation capacity of the river.

In October 1946 a similar outflow of algae (Aphanizomenon flosaquae) from Lake Kegonsa in Wisconsin into the Yahara River caused a fishkill of major proportions. The mechanism of fish destruction was an interaction of oxygen depletion and relase of toxic agents during algal decay.

At Seattle it became evident by 1950 that changes were occurring in Lake Washington, apparently related to input of treated sewage from the surrounding populated area. It was observed that the standing crop of algae in the lake, the level of phosphorus and the oxygen deficit in the deep water hypolimnion all were increasing. These were noted as generally accepted symptoms of eutrophication. As a result of a $85 million program to divert sewage away from the lake, completed in 1967, improvements already have been noted.

WHAT MAKES THE BIOLOGICAL SYSTEM GO?

To visualize better the interaction between eutrophication forces and conditions of impoundment, it is necessary to consider some of the growth requirements of algae. While it is acknowledged that light, suitable temperature, and quiescent water are contributory to algal growth, attention is directed most frequently to the nutrient requirements. Some ten major and several micro-nutrient elements are required for growth, but nitrogen and phosphorus receive greatest emphasis whenever nutrient limitation is considered as a potential remedial mechanism.

In reference to the significance of nitrogen and phosphorus, it should be pointed out: (a) that the peoples of the world have long been involved in rearranging the distribution of these two elements in the environment so that concentrations in surface waters increase; (b) that in some

waters, at least, the size of the plant crop is determined by the availability of nitrogen and/or phosphorus; (c) it is frequently observed that if more nitrogen and phosphorus are added to a given water, more plant material is produced; and (d) while no precise nitrogen-phosphorus ratio is recognized, a ratio in the neighborhood of 10 to 1 generally seems favorable.

While acknowledging that the size of the plant crop is conditioned by nitrogen and phosphorus availability, past observations on a limited number of lakes suggest the following: (a) if soluble phosphorus is present in the amount of about 0.4 oz. per acre-foot (0.015 mg/l), this is sufficient phosphorus to support a population density that people may find objectionable, and (b) for inorganic nitrogen, the corresponding level is about 0.5 lb. per acre-foot (0.3 mg/l).

In the production of aquatic plants in reservoirs, it makes no difference whether the sources of nitrogen and phosphorus as nutrients are the natural soil of the watershed, municipal sewage, or some other kind of waste. If the water of the reservoir is sufficiently fertile and clear enough for effective light penetration, the water is fine for plant production.

WHERE DO NUTRIENTS COME FROM?

If nutrient limitation is to be considered as a potential remedy, it is necessary to know the origin of nutrients and their interactions within the reservoir and the biological systems. Nationwide, a major source of nitrogen and phosphorus is the treated or untreated sewage from cities. It has been estimated that 260,000,000 lbs. of phosphorus are discharged annually in this form. If this sewage discharge represents a volume of 450,000 billion gallons, the resulting phosphorus concentration could approximate 0.27 mg/l--eighteen times the critical level cited above.

Similarly, the estimated annual nitrogen discharge is 511,000,000 lbs., giving an estimated concentration of 1.35 mg/l--four and a half times the critical level. Cities also yield nutrients in their surface runoff and in storm drainage that do not pass through the sanitary sewer system. At present, the magnitudes of such sources are not well known.

As remedial programs curtail the nutrient input from cities and industries, the remaining input that results from runoff from agricultural and other lands take on an added significance.

The quantities leaving agricultural land are variable depending upon land use, slope, and soil characteristics, but for phosphorus has been noted to reach 2 lbs. or more per acre per year and for nitrogen

from 0.06 to as much as 3 lbs. per acre per year. In the United States about a million tons of phosphorus are applied as fertilizer each year.

One can wonder how much of this finds its way to surface waters, but presently the answer is not known. If, however, as much as 10 percent reaches streams, the average concentration could be 0.05 mg/l--about five times the critical levels. Some recent observations suggest that the percent loss is much less-perhaps about one percent.

There is concern about nutrient inputs from feedlots and poultry factories, expecially when they are situated adjacent to watercourses. Some idea of the potential impact of these sources is indicated by the fact that one ton of fresh cow manure contains 1.7 lbs. of phosphorus and poultry manure contains 6.9.

At some localities wild waterfowl must be acknowledged as a potentially significant source of phosphorus input. The estimated amount is 0.45 lb. of phosphorus per bird per year. In Upper Klamath Lake, for example, with its high density waterfowl population, this source of input may be significant--perhaps as great as two percent of total input. Even rainwater, which we ordinarily think of as an example of pristine purity, can be a notable contributor of nitrogen and phosphorus. Limited sampling in some geographic areas suggests that nitrogen input may commonly reach 5.5 lbs. per acre per year and phosphorus may reach a concentration in rainfall from 0.01 to 0.03 mg/l. Significance of precipitation as a nutrient source is under study in several laboratories.

The nutrients that enter a given reservoir also recycle within the biological system. The nutrient substance of a given alga is released upon death and decay and is made available for uptake by a succeeding generation. It has been observed in connection with phosphorus, for example, that the recycling interval may vary from more than a year to as little as minutes, depending upon organism size.

The smaller the organism, the faster the recycling rate. There is also recycling from bottom sediments. Research underway is designed to delineate the nature of the recycling, identify the factors that contribute to it, measure the magnitudes under circumstances, and seek means by which recycling from sediments can be impeded.

In addition to these avenues of nutrient access, consideration must be given also to the ability of certain blue-green algae to fix atmospheric nitrogen to a form acceptable for algal use. This is a factor that must be considered in connection with the total management of nutrient input.

REMEDIES

In the light of the foregoing orientation, it is possible now to consider remedial approaches that may be taken toward the objective of turning back or slowing down the eutrophication processes. The first step is to recognize that each lake and each eutrophication problem is unique unto itself.

Therefore, it is necessary that first effort be devoted to a thorough assessment of the problem at hand. One must ask: What is the role of phosphorus, of nitrogen? What nutrients must be curtailed? What laboratory approaches can be used to evaluate the nutrient regime as a backup to scientific judgment? Once an assessment of the problem has been made it is possible to judge if nutrient limitation is the remedial approach of choice.

If so--and this usually is the case--consideration must be given to the procedures by which phosphorus, and less often other nutrients, can be kept at low levels.

If the indicated decision is to curtail phosphorus input in all manageable ways, the following possibilities come to mind: (a) diversion of nutrient-bearing municipal or industrial wastes away from the lake--a practice already in being at two or three locations; (b) tertiary treatment of wastes for phosphorus removal--a mechanism technologically now available; (c) improvement in agricultural practices so as to cut down nutrient contributions--technology toward this objective has not been completely developed; and (d) prevention of soil erosion--a procedure for which technology and experience are available.

Also to be considered are the possibilities for retrieval of nitrogen and phosphorus from reservoirs. While it would be desirable to have effective and economical chemical processes for this purpose, none are now available. As an alternative, attention has been directed to harvesting aquatic organisms so that the nutrient substance of which they are composed can be retrieved from the water.

It is not uncommon for the natural algal crop to attain a density of 2 tons per acre, but such mass contains only about 1.5 lbs. of phosphorus and about 15 lbs. of nitrogen. It seems obvious that with this low return of nutrients for the high cost of algal harvesting, the outlook to use this as a practical remedial measure is not presently favorable. With rooted vegetation, however, it is not uncommon for the crop to reach more than 7 tons per acre, containing in the neighborhood of 3.2 lbs. of phosphorus and about 32 lbs. of nitrogen. Effective harvesting equipment is now available.

Therefore, in addition to the physical improvement that results from harvesting waterweeds, a notable nutrient removal benefit can be enjoyed. While one can also consider harvesting other aquatic organisms, such as fish, as a means to remove plant nutrients, the effectiveness of such procedures has not been determined.

Consideration is sometimes given to dredging bottom sediments as another means of removing substantial quantities of plant nutrients from the body of water. This may also impair nutrient recycling between bottom sediments and the overlying water. At present, the reactions of a body of water to such treatment are not predictable. Dredging and all of the other nutrient retrieval approaches cited above are under study at the present time in research programs of the National Eutrophication Research Program, Federal Water Pollution Control Administration.

In addition to these approaches, exploration is being made of other potential remedies. Among them are destratification or prevention of stratification in impoundments, non-dredging impairment of nutrient recycling from sediments, preparation of reservoir sites so as to minimize the availability of nutrients when initial inundation occurs and, finally, whatever approaches are possible to maintain as great a depth in relation to surface area as is possible in the impoundment. This latter is for the purpose of having an arrangement in which the smallest possible volume participates in the activity of photosynthesis, and thus production of plant material.

IMMEDIATE GOALS

From this point in history, immediate movement toward several goals is exceedingly important.

First, there should be agreement on a national policy to stop in every way possible the presently active rearrangement of nutrients in the environment.

Second, there should be curtailment of nitrogen and phosphorus input to reservoirs and lakes in all possible ways now available.

Third, there should be movement toward definition of water quality standards designed to prevent eutrophication in reservoirs and other potentially susceptible waters.

And, fourth, there is need to move forward boldly through expanded and intensified research to develop and perfect the remedial tools needed.